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SOIL CONSERVATION SERVICE

RAINFALL AND RUNOFF CHARACTERISTICS ON A SMALL WATERSHED IN THE SOUTHERN PIEDMONT

By

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Soil Conservation Service – Research

In cooperation with Georgia Agricultural Experiment Stations

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FIGURE 1.--Watershed map.

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SUMMARY

Rainfall and runoff measurements were made during the 12-year period 1940-51 on a bench-terraced field of 19.2 acres comprising a unit watershed on the Southern Piedmont Conservation Experiment Station near Watkinsville, Ga. The Cecil soil, degree of slope, topography, and cropping were representative of many sloping cropland fields throughout approximately 22 million acres of land in the Southern Piedmont area of the United States.

This area was cropped under a 2-year rotation of oats, cowpeas, and cotton through 1943. Corn and kudzu were planted in 1944. The kudzu developed into a thick stand in 1946 and remained on the field throughout the rest of the period of record.

The cropping practices had a marked effect on the runoff characteristics of this field. Thunderstorm rains of high intensity and short duration resulted in high rates of flow under a 2-year rotation of oats, cowpeas, and cotton. Rains of long duration, large volume, and low intensity also caused large volumes of runoff with this cropping practice. The rate of flow responded quickly to changes in the rainfall intensity.

The highest runoff rate (2.31 inches per hour) occurred when rains of high intensity fell on saturated ground with a poor cover of dormant thin-stand kudzu. After kudzu became fully established, the thunderstorm rains usually were absorbed completely and only the rains of long duration and large volume caused appreciable runoff. Even with such rains, the rate of flow was always very low and never exceeded 0.5 inch per hour.

The probable peak rates of runoff for frequencies ranging from 2 to 50 years, computed from the recorded rates, were 1.47 to 2.88 inches per hour for the oats, cowpeas, and cotton and 0.24 to 0.75 inch per hour for the kudzu.

In each year there were periods of 6 or more months in which there was no appreciable runoff. A pond depending on runoff from this watershed for its water supply would need to be designed for sufficient storage to last through such extended periods of limited runoff.

[1] Submitted for publication September 1952.

This study, one of a series located in typical problem areas throughout the country, was conducted at the Southern Piedmont Conservation Experiment Station, Watkinsville, Ga., under the supervision of the Division of Drainage and Water Control, Soil Conservation Service--Research, in cooperation with the Georgia Agricultural Experiment Stations.

The authors extend their sincere thanks to their associates in the Soil Conservation Service who gave advice and assistance during the several years of this study; also to Dr. E. B. Browne, Resident Director, College Experiment Station, and Professor R. H. Driftmier, Chairman, Division of Agricultural Engineering, both of The University of Georgia, who reviewed the manuscript and made helpful suggestions. The Soil Conservation Service members of the project staff were transferred to the Bureau of Plant Industry, Soils, and Agricultural Engineering on November 23, 1952.

DESCRIPTION OF THE AREA

A watershed of 19.2 acres typical of the Southern Piedmont runoff-problem area was selected on the Southern Piedmont Conservation Experiment Station at Watkinsville, Ga. This watershed has vegetated bench terraces and land slopes ranging from 3 to 10 percent, the average slope being about 7 percent. The soil, a moderately eroded Cecil, is developed from residual soil material derived from metamorphic and igneous granitic rock. In different parts of the watershed the texture of the surface soil ranges from sandy loam to clay loam because of prior erosion and deposition.

Uneroded Cecil soil has a grayish-brown sandy loam topsoil about 6 to 8 inches deep which is underlain by a B horizon of red clay ranging from 2 to 5 feet in thickness. This grades into the C horizon which is usually several feet deep and has porous, decomposed rock material resting on solid parent rock. This soil is similar to that on about 22 million acres in the Piedmont area of Alabama, Georgia, and South Carolina.

The terraces had been established many years ago and were practically level. Bermudagrass and weeds had been allowed to grow along the terraces to prevent overtopping of the ridges and resultant gullying. Throughout the years, however, water overtopped the terrace ridges at various places, causing scouring below the ridges and deposition above the successive ridges downslope. As a result, the soil now generally has an exposed B horizon below each terrace, a nearly normal profile in the mid-interval area, and fill material immediately above each terrace. The conformation of the field resembles a series of benches, hence the name "bench terraces" by which they are commonly known.

A topographic map of the field is shown in figure 1.

The terraces in this field are not refined or finished structures. They are the product of erosion below and deposition above small grassed ridges established in previous years on the approximate contour. They modify only slightly the natural runoff pattern of the field. Also, their effect on overland flow is probably very small compared to that from well-designed and well-built channel-type terraces that control the passage of runoff water to specified outlets. They are representative, however, of many old fields in the Southern Piedmont.

PLAN OF STUDY

Rates and amounts of rainfall and runoff were determined for the 19.2-acre field under two distinct types of cropping treatments--one which permitted active erosion in the early years of the study, followed by a later treatment which provided complete soil stabilization. During the first period the crop cover was not enough to hold the soil, and the tillage practices were conducive to runoff and erosion. In the second period, an excellent ground cover gave a high degree of protection.

The cropping plan from the beginning of the study to the end of 1944 was a 2-year rotation of (1) oats for seed, then cowpeas for hay; and (2) row crop. The oats were planted in the fall of each row-crop year. After they were harvested in June the land was turnplowed with a disk-tiller, and cowpeas were broadcast seeded. Oats and cowpeas were grown in 1939, 1941, and 1943; cotton in 1940 and 1942. In 1944, corn was planted as a row crop between rows of kudzu spaced 20 feet apart. The kudzu made little growth that year and was cultivated along with the corn. Kudzu growth was better in 1945, and by early summer of 1946 a thick growth had developed. Grazing the kudzu with beef cattle was begun in the summer of 1950, and in September 1950 the field was disk-harrowed and oversown to rescuegrass.

Rainfall and runoff measurements were begun on September 13, 1939. Rainfall amounts and intensities were measured with a Fergusson-type weighing and recording raingage, and the rainfall volume was checked with a U. S. Weather Bureau "standard" gage. Runoff rates and amounts were obtained from water-level readings recorded with a Friez type FW-1 recorder. This instrument was located at the watershed outlet near a concrete broad-crested 2 to 1 V-notch weir. The details of the gaging site and gaging station are shown in figures 2 to 7, inclusive.

The recorded measurements were analyzed to discover significant relationships between the cover factors and such hydrologic factors as intensity and duration of rainfall, antecedent moisture conditions, and peak runoff rates.

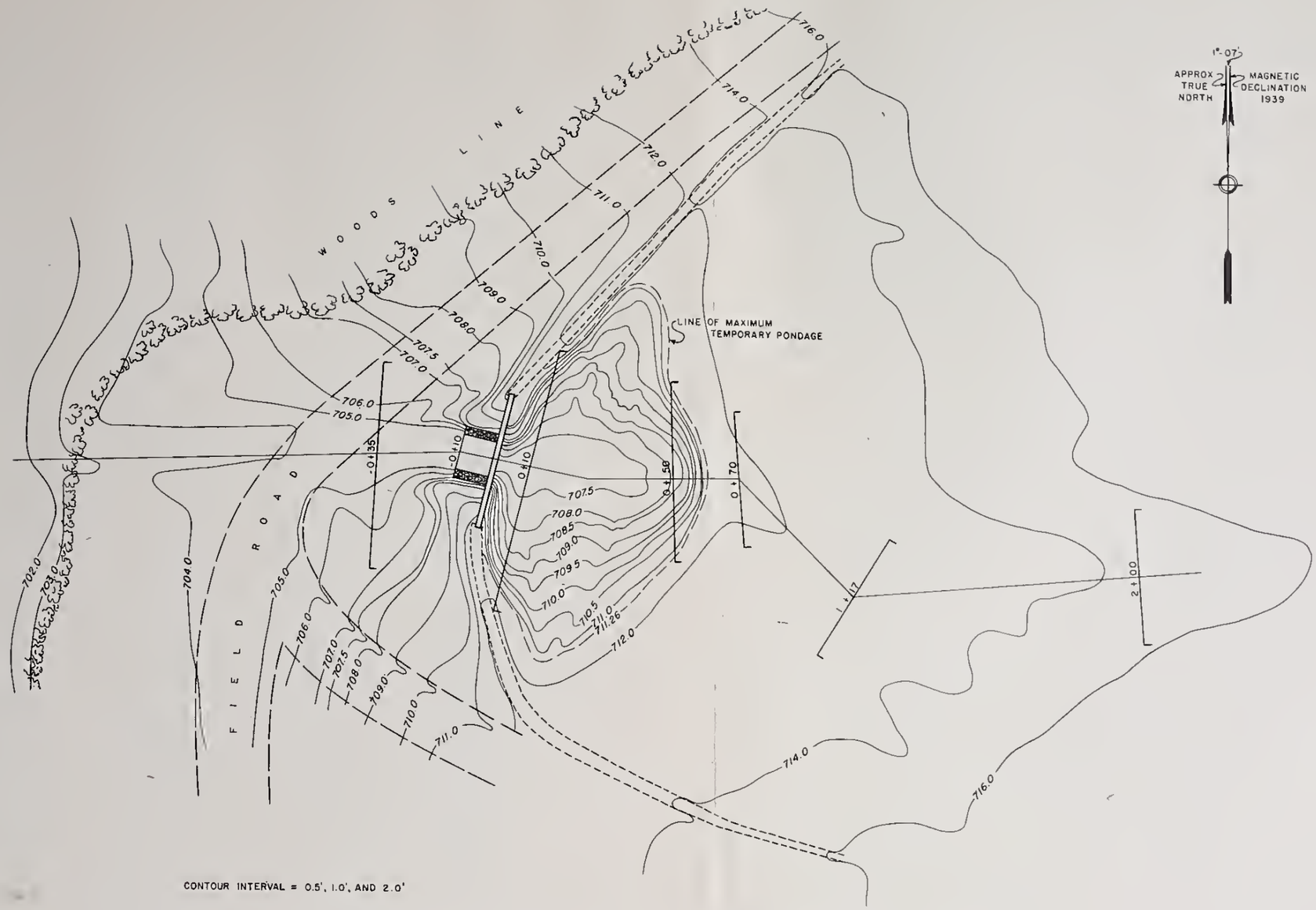
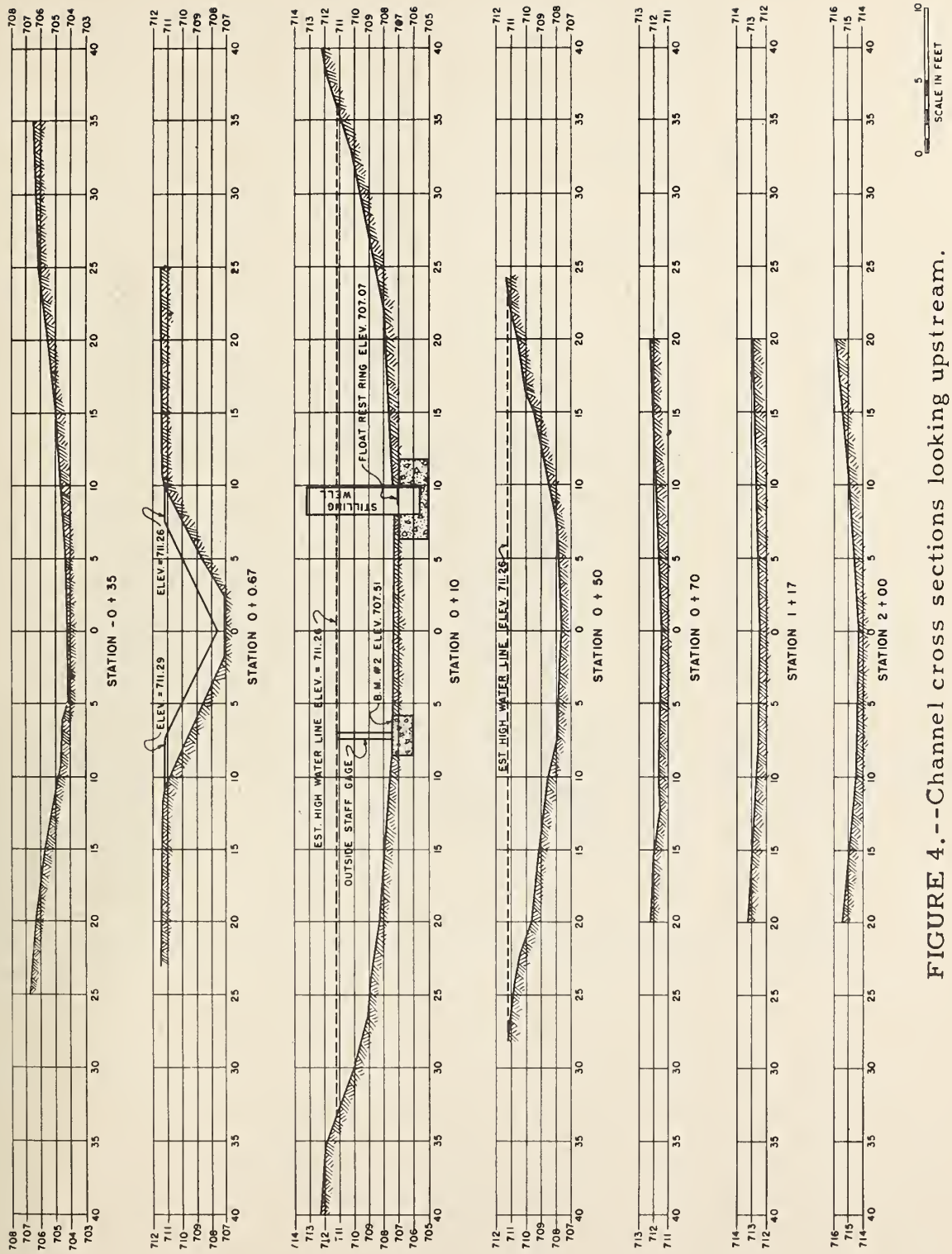


FIGURE 2.--Topography of gaging site and channel.

FIGURE 3.--Profile through gaging site.

(Face p. 2)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STATION 0 + 0.67
ELEV. = 711.29
ELEV. = 711.26
STATION 0 + 10
EST. HIGH WATER LINE ELEV. = 711.26
OUTSIDE STAFF GAGE
B.M. #2 ELEV. 707.51
STILLING WELL
FLOAT REST RING ELEV. 707.07
STATION 0 + 50
EST. HIGH WATER LINE ELEV. 711.26
STATION 0 + 70
STATION 1 + 17
STATION 2 + 00
SCALE IN FEET

FIGURE 4.--Channel cross sections looking upstream.

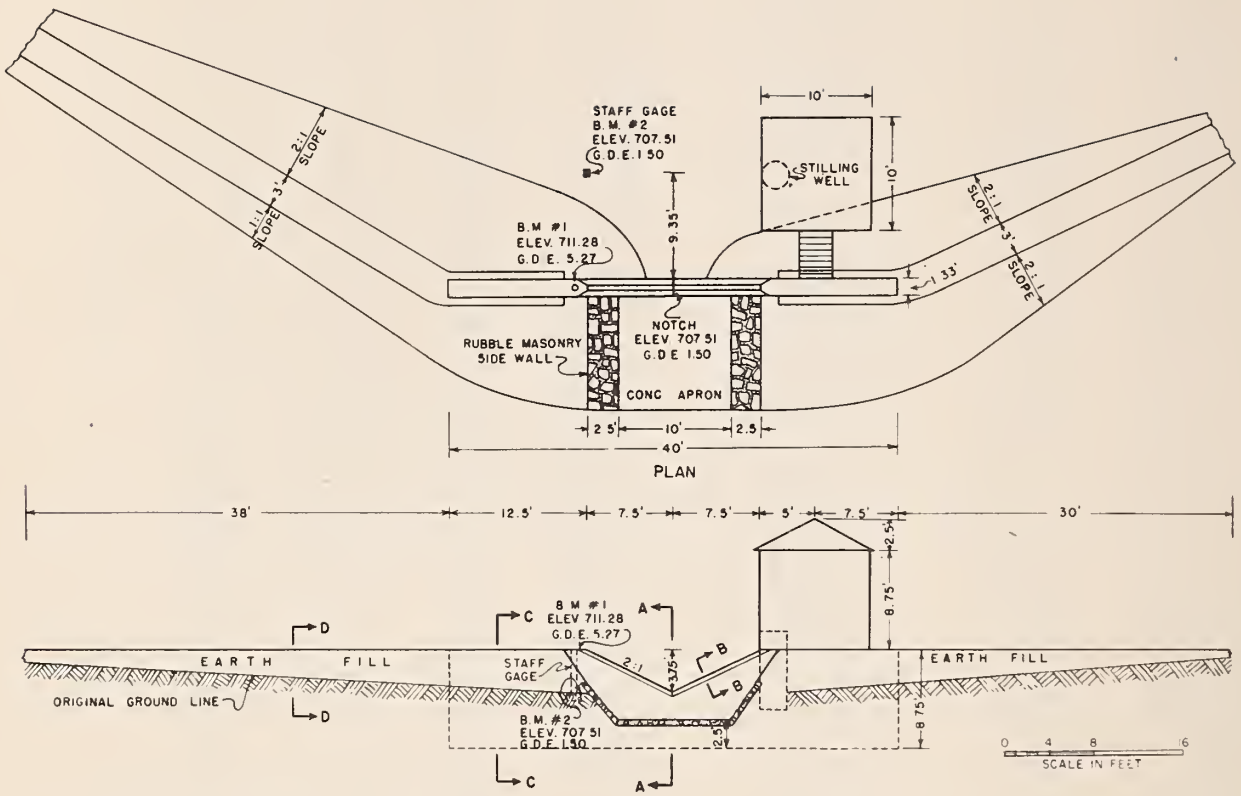

FIGURE 5.--Gaging station (elevation looking upstream).

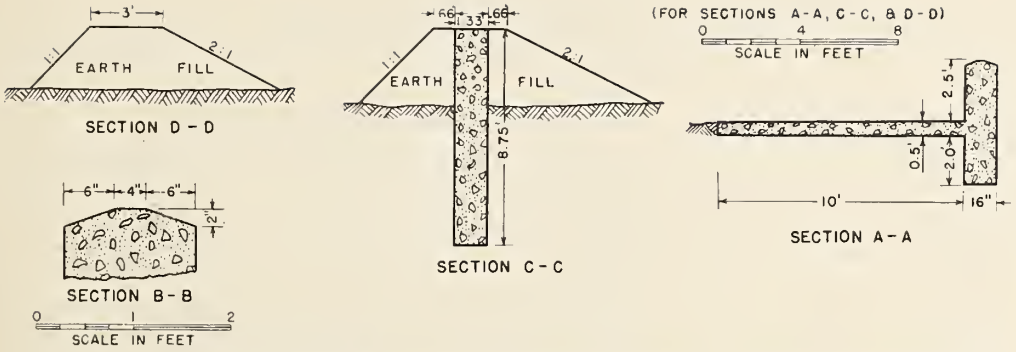

FIGURE 6.--Sections through notch and wings.

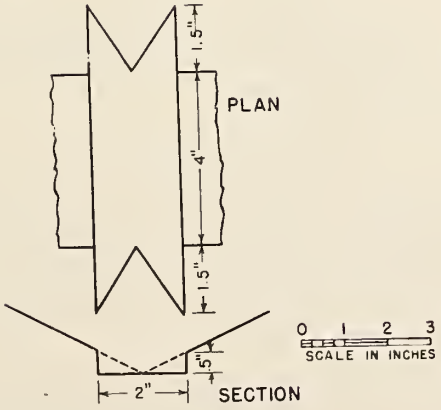

FIGURE 7.--Details of notch.

RUNOFF CHARACTERISTICS

Oats, Cowpeas, and Cotton Cover

The runoff characteristics during the oats-cowpeas years were similar to those during the years when the land was in row crops of cotton and corn. Runoff data during the years 1939-42 for separate fractional-acre runoff plots on a 7-percent slope located elsewhere on this station showed similar trends when these crops were grown.

The monthly rainfall and runoff for the years 1940-44 for the watershed under oats, cowpeas, and cotton are given in table 1. The monthly rainfall varied widely from the 59-year average monthly rainfall for this locality. But this variation was within that expected when compared with U. S. Weather Bureau records for this area.

TABLE 1.--Monthly rainfall and runoff for 1940-44 on watershed W-I in oats, cowpeas, and cotton, near Watkinsville, Ga., and 59-year average rainfall for the locality

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
		In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1940	Rainfall	5.13	4.87	4.38	2.49	2.03	4.08	4.33	12.69	0.37	0.88	4.05	4.27	49.57
	Runoff	.08	.57	.09	.01	.01	.20	.25	4.27	0	0	0	.02	5.50
1941	Rainfall	2.32	1.59	5.41	.74	.60	4.08	8.13	2.63	1.66	1.68	1.33	7.84	38.01
	Runoff	.05	0	.26	0	0	.31	3.04	.07	.05	0	.02	1.42	5.22
1942	Rainfall	2.81	3.42	9.19	1.03	7.13	2.02	2.79	8.87	3.07	4.32	.70	6.19	51.54
	Runoff	.01	.09	2.00	0	1.83	0	.01	3.39	.34	.33	.03	1.71	9.74
1943	Rainfall	7.75	1.05	6.68	5.70	1.92	8.05	8.74	1.28	3.18	.27	2.29	4.23	51.14
	Runoff	3.82	.06	.73	1.43	.02	1.37	2.68	0	0	0	.02	.15	10.28
1944	Rainfall	3.94	7.60	9.46	6.77	1.90	1.08	2.97	3.33	3.27	1.74	1.97	2.32	46.35
	Runoff	.42	1.53	3.26	2.15	0	0	.11	.01	.01	0	0	0	7.49
5-yr. av.	Rainfall	4.39	3.71	7.02	3.35	2.72	3.86	5.39	5.76	2.31	1.80	2.07	4.97	47.31
	Runoff	.88	.45	1.27	.72	.37	.38	1.22	1.55	.08	.06	.01	.66	7.65
1885-1943 rainfall average		4.67	4.85	5.10	3.66	3.60	4.13	5.22	4.79	3.31	3.00	2.61	4.55	49.49

The amount of runoff was affected primarily by the intensity, amount, and duration of each storm, and by the soil moisture as affected in turn by the time lapse since the preceding storm. Storms of high intensity produced runoff when the amount and duration exceeded the capacity for surface retention. Runoff resulted from low-intensity storms only when the ground had been thoroughly wetted by the current or preceding storms.

Rainfall and runoff data for the 9 storms that produced the highest rates of runoff during the 1940-44 period are presented in table 2. (A runoff rate of 1.0 inch per hour is equal to a flow of 19.35 cubic feet per second over the weir.) The peak rate of runoff measured (1.96 inches per hour) was from the rain of July 11, 1941. Many rains were larger in volume of rainfall, but this storm had rainfall of higher intensities than any other. The intensities for the 5-, 10-, 15-, and 30-minute periods (table 2) did not exceed those shown by Yarnell[2] to be expected each year. The expected 2-year intensities for this area are 6.09, 4.99, 4.32, and 3.02 inches per hour for 5, 10, 15, and 30 minutes, respectively.

The rainfall-runoff relationships for the high-intensity storm of July 11, 1941, are illustrated in the hydrograph in figure 8. The soil was fairly dry before this rain. The rain began with an intensity of 2.76 inches per hour, and runoff began almost immediately. The peak runoff rate

[2] Yarnell, D. L. Rainfall Intensity-Frequency Data. U. S. Dept. Agr. Misc. Pub. 204. 1935.

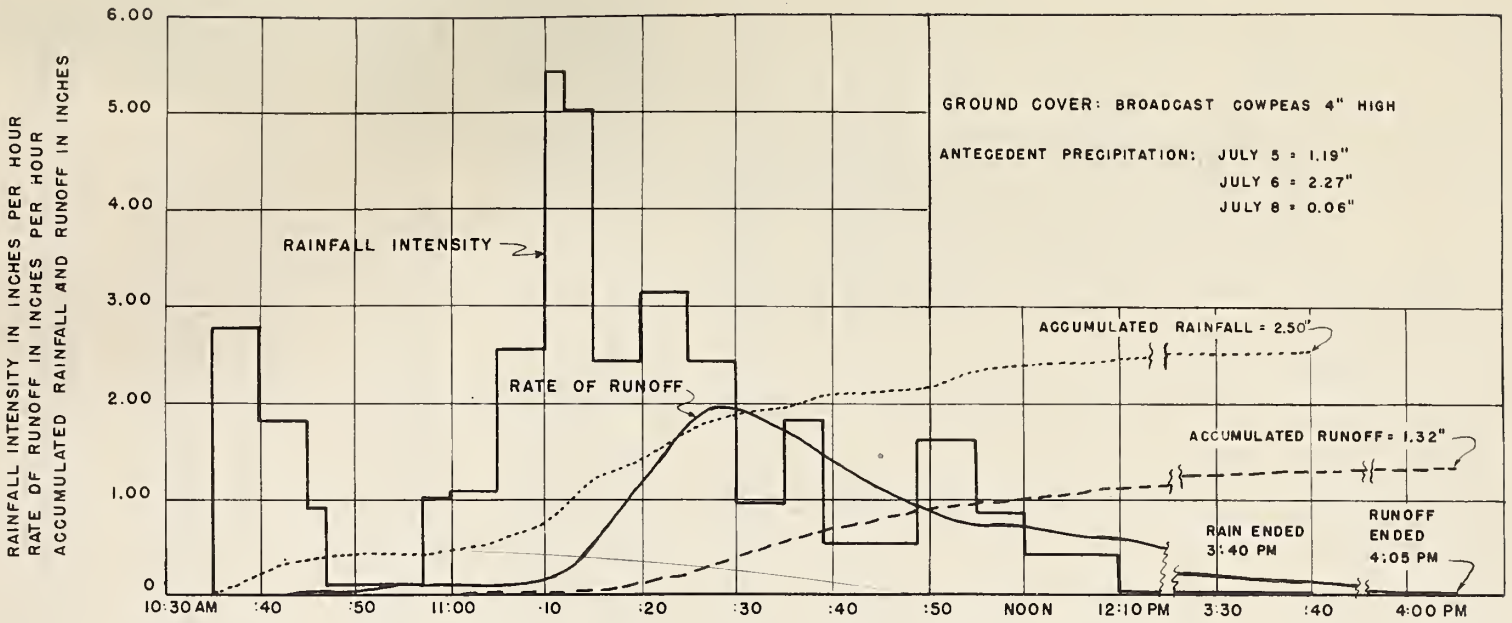

FIGURE 8.--Hydrograph of rainfall and runoff on watershed W-I, July 11, 1941, Southern Piedmont Conservation Experiment Station, Watkinsville, Ga.

TABLE 2.--Amounts and rates of rainfall and runoff for the principal storms for 1940-44 on watershed W-I near Watkinsville, Ga.

Date	Rainfall					Runoff			Remarks
	Amount	Maximum rate for				Amount	Maximum rate		
		5 min.	10 min.	15 min.	30 min.				
	Inches	*In./hr.*	*In./hr.*	*In./hr.*	*In./hr.*	*Inches*	*C.f.s.*	*In./hr.*	
Aug. 12, 1940	7.11	3.84	2.76	2.56	1.90	2.46	20.1	[1] 1.05	Cotton 18-24 inches tall. Soil very wet with 13 hours of continuous rain.
Aug. 29, 1940	2.50	1.88	1.56	1.52	1.20	1.10	16.9	.88	Cotton mature. Soil very wet.
July 11, 1941	2.51	5.16	3.78	3.56	2.78	1.32	38.0	[1] 1.96	Broadcast cowpeas 4 inches high. Soil moist.
May 15, 1942	1.99	3.84	3.60	3.20	2.28	1.14	24.4	1.26	Cotton 4 inches tall. Soil very wet.
Aug. 16, 1942	1.60	3.00	2.70	2.56	2.46	.60	16.9	.87	Cotton maturing. Soil moist.
Aug. 17, 1942	2.10	3.96	3.36	3.28	2.40	1.25	30.7	[1] 1.59	Soil wet.
Jan. 18, 1943	3.68	4.92	3.72	2.80	1.52	2.53	28.5	[1] 1.48	Oats 2 inches high. Soil wet and settled.
June 10, 1943	1.23	4.56	3.48	2.96	2.08	.70	23.9	1.24	Oat straw on ground. Soil wet.
Apr. 26, 1944	2.07	3.36	2.64	2.12	1.54	1.26	21.4	[1] 1.11	Corn 4 inches tall. Soil moist.

[1] Peak rate of runoff for the respective year.

of 1.96 inches per hour was reached 16 minutes after the rainfall attained maximum rate. One hour after the rainfall stopped the runoff ended. A broadcast stand of cowpeas 4 to 6 inches high together with the oat straw left by the disk-tiller plow furnished fair ground cover.

The rain of August 12-13, 1940, totaling 7.11 inches, was the largest in volume of any rain recorded during the 5-year period. Rainfall intensity was low except for short periods with moderately high rates. Two such periods are shown in the hydrograph illustrating the latter portion of this storm (fig. 9). After 5 inches of rain had fallen there was a period of 5 minutes with an intensity of 3.00 inches per hour which resulted in a runoff rate of but 0.78 inch per hour. During a later 5-minute period when the rainfall intensity rose to 1.80 inches per hour the runoff rate was but 0.35 inch per hour. These low runoff rates indicated that the time of concentration was in excess of 5 minutes.

Analyses of the data in table 2 and the hydrographs for these rains indicate that the percentage of storm rainfall that ran off was more closely related to the intensity of rainfall during the time of concentration for the watershed than to the total amount of rainfall for the storm. A study of the runoff from these storms indicated that the time of concentration was approximately 15 minutes.

Rainfall intensities for both 10- and 15-minute periods were higher for the storm of July 11, 1941, than for the other storms recorded. This storm also produced the highest peak rate of runoff (1.96 inches per hour) with over 52 percent of the rain running off. The storm of August 17, 1942, had the second highest 15-minute rainfall rate and the second highest runoff rate, with 59 percent of the rain running off. The storm of January 18, 1943, had the second highest 10-minute rainfall rate and the third highest runoff rate, with runoff equal to 69 percent of the rainfall. No rain recorded had a sustained uniform high rate from which the time of concentration on the field could be precisely determined.

The data for the rains of August 16-17 and 17-18, 1942, respectively, show that soil moisture materially affected both the rate and volume of runoff. The soil was fairly dry before the rain on August 16. A maximum 15-minute rate of 2.56 inches per hour gave a peak runoff rate of 0.87 inch per hour, or only 34 percent of rainfall intensity.

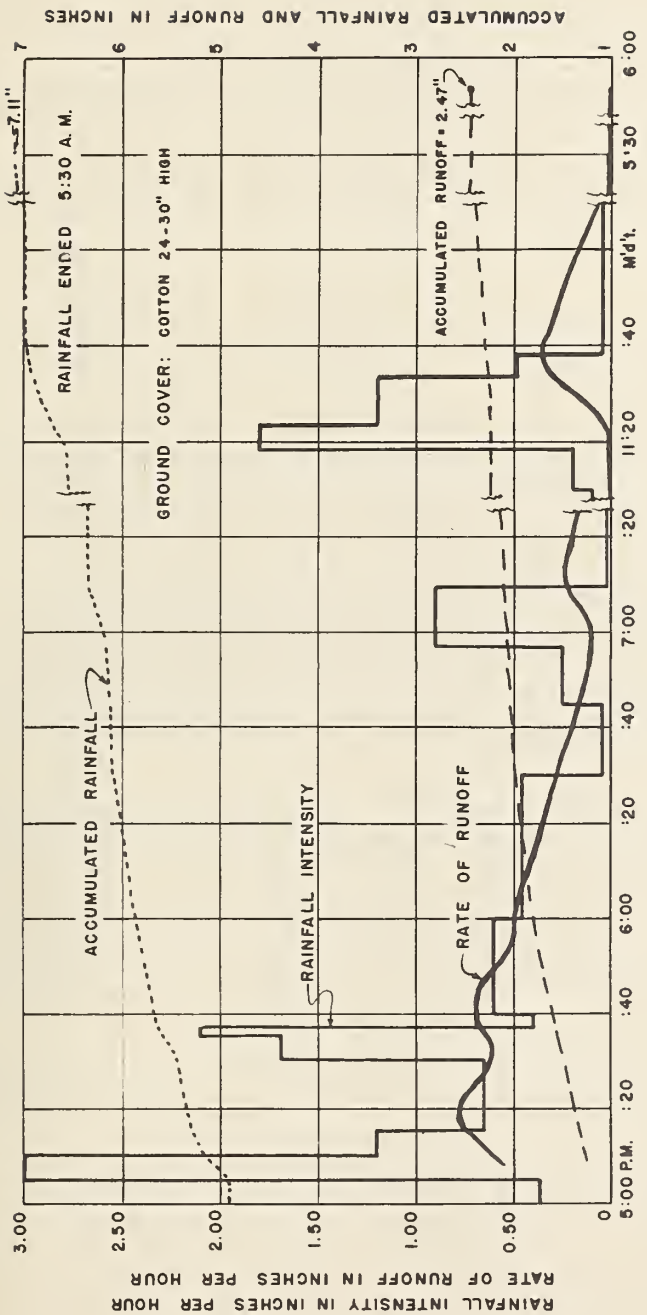

FIGURE 9.--Hydrograph of rainfall and runoff on watershed W-I for the latter part of the rain of August 12-13, 1940, Southern Piedmont Conservation Experiment Station, Watkinsville, Ga.

On August 17, with wet soil, the highest 15-minute rainfall rate was 3.28 inches per hour and the peak runoff rate was 1.59 inches per hour, or 49 percent of the rainfall intensity.

The volume of runoff from the dry soil was only 38 percent of the rainfall. The next day, however, when the ground was wet, the runoff was 60 percent of the rainfall.

Runoff from the oats, cowpeas, and cotton was always muddy and heavily laden with soil material. Sand deltas formed at many places on the field and above the weir at the gaging site. Much material was also carried off and deposited in downstream channels and reservoirs.

Runoff and soil-loss measurements were made during 1940-43 on 1/30-acre plots of 7-percent slope and 70-foot length at another site on the station. The average annual amounts of rainfall, runoff, and soil losses from plots of oats-cowpeas and cotton during that period were as follows:

	Oats-cowpeas	Cotton
Rainfall ..... inches	47.77	47.77
Runoff ..... inches	11.18	9.35
Soil loss ..... tons per acre	9.75	10.89

The soil surface under the oats and cowpeas was smooth and compacted most of the year. This was more conducive to runoff than where cotton was grown. The oats and cowpeas, however, provided a little more ground cover during the year and permitted slightly less soil loss than was measured from the cotton. (Soil losses were not measured on the 19.2-acre watershed.)

Kudzu Cover

The kudzu on the watershed made sparse growth in 1945. Weeds were controlled by disking between the rows, and throughout 1945 and the first 5 months of 1946 the ground-cover conditions were fairly similar to those under the oats-cowpeas cropping practice. Kudzu did not effectively control the runoff from the field until May 1946 when it developed a good growth with runners spreading generally over the entire area. After May 1946, the ground was covered each growing season with a thick canopy of leaves and vines. A dense mulch formed on the soil surface each fall when frost killed back the leaves and succulent vines. This mulch was effective throughout the growing season also.

The highest rate of runoff during the entire 12 years of record occurred during the storm of January 5-6, 1946, before the kudzu was fully established. The ground cover at that time was a thin stand of dead weeds in dormant kudzu and was about comparable to the cowpea stubble of previous years.

A hydrograph of part of this storm is illustrated in figure 10. The period of highest rainfall intensity occurred after 3.4 inches of rain had fallen in 24 hours. A maximum rate of 8.10 inches per hour for 2 minutes was recorded. Other high rates during this storm were 5.76 and 4.48 inches per hour for 5 and 15 minutes, respectively.

The peak rate of runoff (2.31 inches per hour) was reached 21 minutes after the rainfall had attained maximum intensity. The total runoff was 3.58 inches, or 61 percent of the total rainfall of 5.87 inches. Although the principal flow was over within 4 hours after the rainfall ended, the runoff did not stop completely until about 35 hours after the rain was over.

With full establishment of the kudzu cover there was a marked change in the runoff characteristics of the watershed. Storms of high intensity, which formerly would have caused peak rates of runoff, usually were absorbed completely without causing runoff, and all the recorded runoff rates were very low.

The intensity of the rain of April 22, 1951, was higher than that of any other storm recorded after the kudzu became established. The hydrograph of this storm (fig. 11) shows that even with maximum intensities of 6.00 inches per hour for 2 minutes and 4.48 per hour for 15 minutes the peak runoff rate was only 0.07 inch per hour. The total runoff from this storm was only 0.08 inch. This runoff pattern is in sharp contrast to that for a similar rain on July 11, 1941, when cowpeas were on this field (fig. 8).

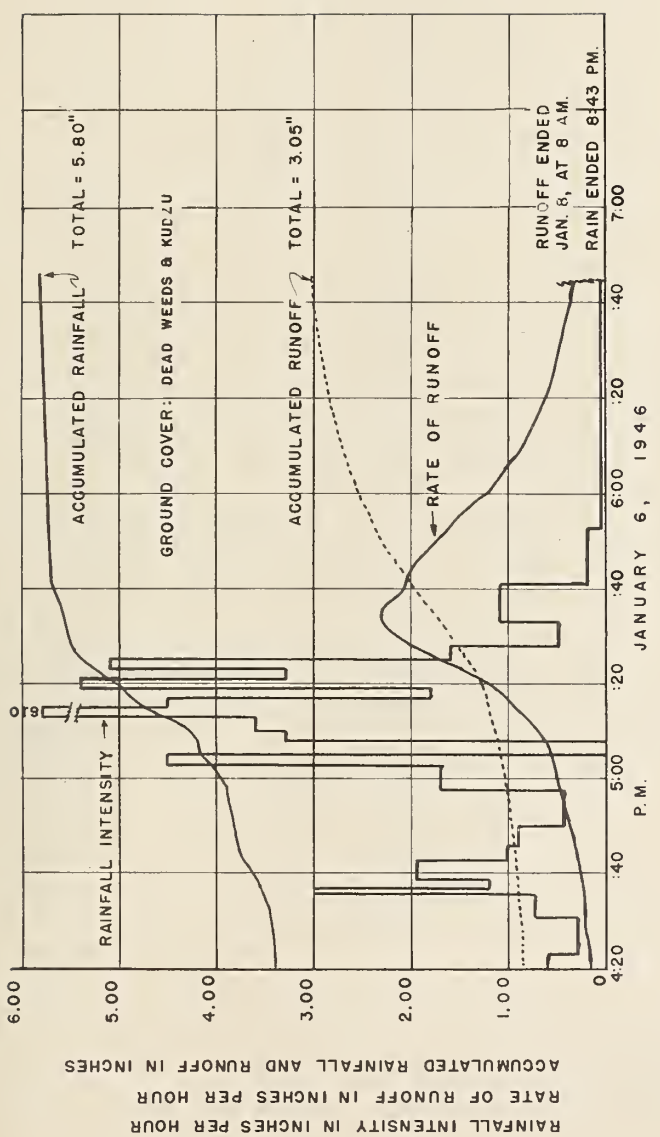

FIGURE 10.--Hydrograph of rainfall and runoff on watershed W-1 for part of the rain of January 6, 1946, Southern Piedmont Conservation Experiment Station, Watkinsville, Ga.

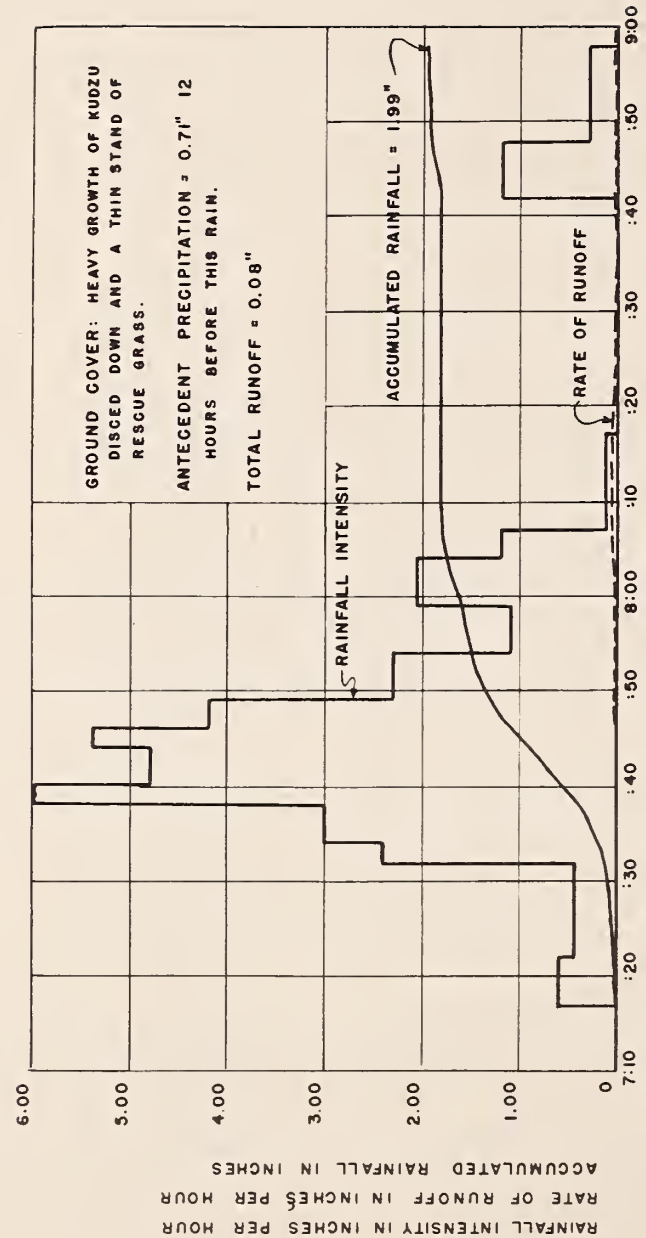

FIGURE 11.--Hydrograph of rainfall and runoff on watershed W-I, April 22, 1951, Southern Piedmont Conservation Experiment Station, Watkinsville, Ga.

Storms of long duration and large volume caused relatively large amounts of runoff from the well-established stand of kudzu, even though these rains were usually low in intensity. Runoff from such storms began when the rain continued after the vegetative cover had been drenched and the soil profile had been filled with water.

The hydrograph for the rain of November 26-30, 1948, (fig. 12) shows these conditions. This rain began at 1:10 p.m. on November 26 at a time when the soil was still very wet from a rain of 4.55 inches that fell during November 19-24. Runoff started about 3 p.m. and reached a peak rate of 0.4 inch per hour at 9:05 p. m. This was 30 minutes after the rainfall had slackened. A period of rainfall intensity of 0.94 inch per hour for 30 minutes just before midnight prolonged the rate of flow at that time but did not appreciably increase the rate. Very little rain fell during the 25 hours from 1:00 a. m., November 27 to 2:00 a. m., November 28, although a small flow of runoff continued during this period.

Most of the rain that fell on November 28 was measured over the weir as runoff. Most of this water penetrated the soil stratum over a major part of the field and returned to the surface as seepage in the lower end of the field. The total rainfall was 7.80 inches and the runoff measured was 6.03 inches, or 77.4 percent of the rainfall.

These runoff characteristics are in bold contrast to those of 1940 when the field was in cotton. The changes in rate of rainfall on August 12-13, 1940, for example, were reflected immediately in the runoff rate (fig. 9). The runoff ended 23 minutes after the rainfall ended, although the total rainfall was 7.11 inches.

The effectiveness of kudzu in reducing runoff is indicated by the data on monthly amounts of rainfall and runoff, for the kudzu phase of cropping on this field (table 3). Only appreciable amounts of runoff were recorded in the months of excessively large amounts of rainfall.

TABLE 3.--Monthly rainfall and runoff for 1945-51 on watershed W-I in kudzu, near Watkinsville, Ga.

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
		In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1945	Rainfall	2.83	7.85	2.28	8.24	2.33	1.16	3.79	2.89	4.85	2.26	2.77	8.12	49.37
	Runoff	0	1.57	0	2.23	.01	0	0	.02	.11	0	0	.99	4.93
1946	Rainfall	9.28	4.83	5.47	4.90	5.16	4.11	2.91	1.50	2.73	4.76	2.04	1.11	48.80
	Runoff	3.66	.52	.52	.65	.15	.14	.02	0	0	.03	0	0	5.69
1947	Rainfall	9.05	1.99	5.78	4.88	3.18	4.50	1.30	3.15	1.53	4.24	8.30	4.66	52.58
	Runoff	2.13	0	.28	.25	0	0	0	0	0	0	.10	0	2.76
1948	Rainfall	4.23	7.63	9.86	1.54	4.59	3.33	4.51	3.69	3.58	1.18	15.61	4.21	63.96
	Runoff	0	2.32	1.19	.11	0	0	0	0	0	0	6.80	.02	10.44
1949	Rainfall	4.21	6.05	2.64	8.07	3.66	2.29	3.60	6.16	3.05	3.58	1.24	2.86	47.41
	Runoff	.49	.23	0	1.52	0	0	0	0	0	0	0	0	2.24
1950	Rainfall	2.21	2.32	5.09	.51	6.47	3.37	5.39	1.17	2.26	7.75	.39	4.14	41.07
	Runoff	0	0	.01	0	0	0	0	0	0	.85	0	.01	.87
1951	Rainfall	1.95	2.05	5.87	5.12	.58	4.30	7.34	.95	3.05	1.88	2.16	6.69	41.94
	Runoff	0	0	.01	.06	0	0	.01	0	0	0	0	.47	.57

Runoff and soil-loss measurements for 1943-50 from kudzu and corn plots on Cecil clay soil at another place on the station bear this out. These plots on an 11-percent slope were 70 feet long and 1/30 acre in size. The crops were grown in a 3-year rotation of kudzu, kudzu, and corn. The average annual rainfall, runoff, and soil losses for the plots for 1943-50, by crop years, were as follows:

	First-year kudzu	Second-year kudzu	Corn
Rainfall ..... inches	47.09	50.76	50.62
Runoff ..... inches	3.89	2.23	3.29
Soil loss ..... tons per acre	.72	.12	.75

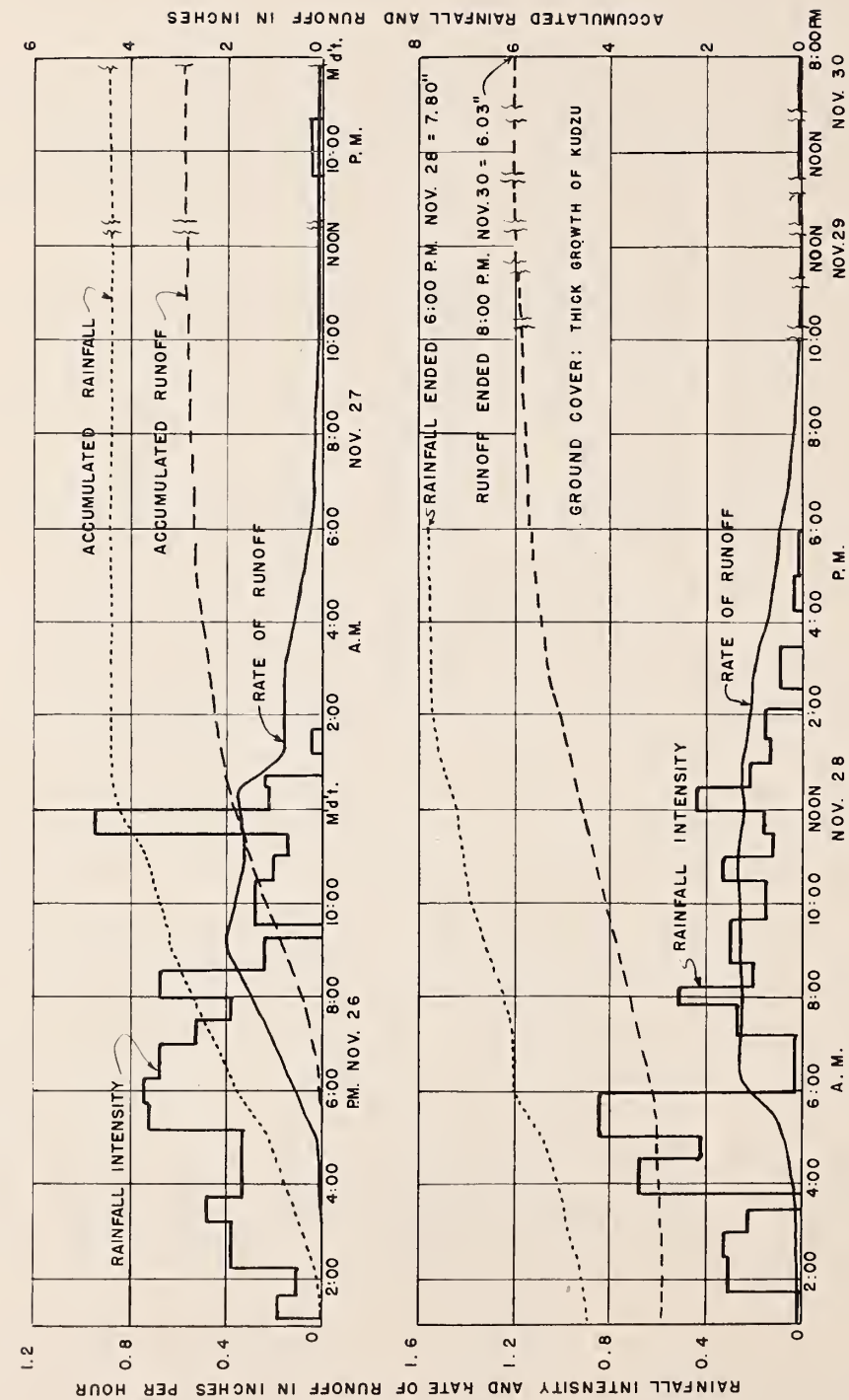

FIGURE 12.--Hydrograph of rainfall and runoff on watershed W-I, November 26-30, 1948, Southern Piedmont Conservation Experiment Station, Watkinsville, Ga.

Although the ground cover of the second-year kudzu was not equal to that of the continuous kudzu on this watershed, both runoff and soil losses were comparatively low, indicating the effectiveness of dense cover such as kudzu for land protection. After the kudzu became established on the field and plots, the water flowing over the watershed weir or into the runoff-plot tanks was practically clear. Therefore, little or no silting of stream channels and reservoirs should occur from runoff from land cropped under a rotation system with periodic reestablishment of a full cover of kudzu.

PROBABLE PEAK RAINFALL AND RUNOFF RATES

The probable peak rates of rainfall for 15 minutes and the peak runoff rates that might be equaled or exceeded once in 2, 5, 10, 25, and 50 years, as computed by the Potter[3] method, are given in table 4. The 5-year periods of January 1, 1940, to December 31, 1944, and June 1, 1946, to May 31, 1951, were selected because the two types of cropping practices were used on the land during these respective periods.

TABLE 4.--Probable 15-minute rainfall rates and peak runoff rates computed by the Potter method based on watershed W-I records for the periods January 1, 1940-December 31, 1944 and June 1, 1946-May 31, 1951, and the 15-minute rainfall rate expected at Watkinsville, Ga.

Recurrence interval in years	Expected 15-minute rainfall rate (Yarnell)	Probable rates (Potter method)			
		Period 1/1/40-12/31/44		Period 6/1/46-5/31/51	
		Rainfall 15-min. rate	Runoff peak rate	Rainfall 15-min. rate	Runoff peak rate
	In./hr.	*In./hr.*	*In./hr.*	*In./hr.*	*In./hr.*
2	4.32	2.96	1.47	3.34	0.24
5	5.18	3.60	1.92	4.48	.40
10	5.96	4.03	2.17	5.24	.51
25	6.69	4.64	2.59	6.28	.65
50	7.43	5.13	2.88	7.07	.75

The maximum 15-minute rainfall rates and the peak runoff rates for each year of these respective periods, on which these computations were based, were as follows:

Period	15-minute rainfall rates (Inches per hour)	Peak runoff rates (Inches per hour)
1/1/40-12/31/44	2.56, 3.56, 3.28, 2.96, 2.12	1.05, 1.96, 1.59, 1.48, 1.11
6/1/46-5/31/51	2.88, 2.44, 4.24, 2.32, 4.48	.23, .20, .40, .14, .20

In comparing these actual 15-minute rainfall rates with those for similar periods as computed by Yarnell (table 4), it is apparent that no rains during the first 5-year period of this study were as intense as could have been expected. Also, the 50-year probable rate, based on the 1940-44 records, is about the same as the rate that could be expected once in 5 years according to Yarnell.

High rates of runoff, however, are to be expected with the oats, cowpeas, and cotton type of ground cover. The runoff from the rain of January 6, 1946, (fig. 10) tends to confirm these probabilities. The conditions at that time--high rainfall intensity, saturated soil, and only a fair ground cover--were all conducive to a high rate of runoff.

The 15-minute rainfall intensities during the 5-year period with kudzu in the rotation were somewhat higher than the rates in the first 5-year period and were more nearly equal to those predicted by Yarnell. The runoff rates from kudzu were very low. The probable maximum rates of runoff, based on the recorded rates, are only 0.24 inch per hour in 2 years and 0.75 inch per hour in 50 years. These are only 16 and 26 percent, respectively, of the probable rates for 2 and 50 years with oats, cowpeas, and cotton on the land. Percentages for the other years lie between these ranges in values.

[3] Potter, W. D. Simplification of the Gumbel Method for Computing Probability Curves. U. S. Soil Conservation Service SCS-TP-78. 1949.

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TABLE 5.--Rainfall and runoff data for periods with little or no runoff on watershed W-I, near Watkinsville, Ga.

Dates	Duration	Rainfall	Runoff	Crop
	Days	*Inches*	*Inches*	
Aug. 31, 1940-Mar. 26, 1941...	218	17.13	1.53	Cotton, then oats
July 29, 1943-Jan. 1, 1944....	188	11.55	3.27	Cowpeas for hay
Apr. 28, 1944-Feb 11, 1945....	287	23.99	2.50	Corn and kudzu
June 17, 1946-Jan. 18, 1947...	216	20.53	.05	Kudzu
Apr. 17, 1947-Feb. 6, 1948....	296	36.09	.10	Kudzu
Apr. 7, 1948-Nov. 22, 1948....	230	26.10	0	Kudzu
May 1, 1949-Oct. 18, 1950.....	536	56.02	.01	Kudzu

Since the maximum 15-minute rainfall rates were below the normal predicted by Yarnell, it is probable that the recorded peak runoff rates were likewise less than the rates that might be expected from fields of this type with the ground covers used. This should be taken into account in using the peak runoff rates given in table 4 for design purposes.

PERIODS WITHOUT RUNOFF

The data on the amounts of rainfall and runoff by months presented in tables 1 and 3 show that in nearly every year there were periods of 6 or more months in which there was little or no runoff. The duration of these periods, together with the total rainfall and runoff, is shown in table 5.

During these long periods of limited runoff, while the oats, cowpeas, and cotton were on the land, the amount of runoff was 9 or more percent of the rainfall. After kudzu covered the ground, however, there was practically no runoff for long periods. In nearly 18 months (May 1, 1949, to October 18, 1950) there was only 0.01 inch of runoff.

These data indicate that there might be long periods without recharge in ponds depending for their water supply on surface runoff from well vegetated kudzu fields. Such ponds would need to be designed for storing a volume sufficient for these long periods of limited runoff.

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